FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: A-7752

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR): 10/030085

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP 00/05935	26.06.00 (26 June 2000)	13.07.99 (13 July 1999)

TITLE OF INVENTION: **IMAGING SYSTEM**

APPLICANT(S) FOR DO/EO/US: **Alexei MIKHAILOV and Dirk HAUSCHILD**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
10/050085	PCT/EP 00/05935	A-7752

24. The following fees are submitted:.	CALCULATIONS PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :	
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1040.00	
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International search fee prepared by the EPO or JPO $890.00	
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $740.00	
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) $710.00	
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =	$890.00
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	$130.00

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	16 - 20 =	0	x $18.00	$0.00
Independent claims	1 - 3 =	0	x $84.00	$0.00
Multiple Dependent Claims **(check if applicable)**.			☐	$0.00

TOTAL OF ABOVE CALCULATIONS =	$1,020.00
☒ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.	$510.00
SUBTOTAL =	$510.00
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +	$130.00
TOTAL NATIONAL FEE =	$640.00
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐	$0.00
TOTAL FEES ENCLOSED =	$640.00
Amount to be: refunded	$
charged	$

a. ☒ A check in the amount of **$640.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **08-2455** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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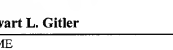
20741

PATENT TRADEMARK OFFICE



SIGNATURE

Stewart L. Gitler
NAME

31,246
REGISTRATION NUMBER

January 10, 2002
DATE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Alexei MIKHAILOV and Dirk HAUSCHILD

Attn: PCT Branch

Serial No.: **Not yet awarded**

Filed :

For : **IMAGING SYSTEM**

PRELIMINARY AMENDMENT

Commissioner of Patents and Trademarks
Washington, D.C. 20231

ATTN: PCT BRANCH

Sir:

Please amend the above-identified application as follows:

In the Claims:

Cancel claims 1-16 and kindly replace them with the claims (17-32) on the attached addendum.

Remarks

The claims have been amended to place them in conformance with U.S. practice and to eliminate multiple dependencies. No new matter has been added.

Respectfully submitted,

Stewart L. Gitler
Reg. 31,256

January 10, 2002

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Attorney Docket: A-7752.PAM/eb

What is claimed is:

17. An imaging system for imaging electromagnetic radiation in an optical spectral range, comprising at least one lens element and at least one first and one second optical functional interfaces through which the electromagnetic radiation can pass, the at least one first and the at least one second optical functional interfaces having at least in sections, a cylinder lens geometry or a cylinder lens-like geometry, so that the at least first and the at least one second optical functional interfaces each have a direction which lies in the at least one first and that at least one second optical functional interfaces and along which at least in sections a curvature of the surface is essentially constant, a direction of essentially constant curvature of the at least one first optical functional interface to the direction of essentially constant curvature of the at least one second optical functional interface being aligned roughly perpendicular to one another, wherein the at least one first, or the at least one second optical functional interface, or both, have an aspherical cylinder lens geometry, or an aspherical cylinder lens-like geometry.

18. The imaging system as claimed in claim 17, wherein the aspherical cylinder lens geometry or the aspherical cylinder lens-like geometry is formed by an elliptical, hyperbolic or parabolic cylinder section.

19. The imaging system as claimed in claim 17, wherein there are at least two lens elements, on one of the lens elements there being a first optically functional interface and on the other of the lens elements there being a second optically functional interface.

20. The imaging system as claimed in claim 19, wherein the at least two lens elements each comprise one of the first or

second optically functional interfaces and a planar entry or an exit surface opposite the interfaces.

21. The imaging system as claimed in claim 17, wherein there is at least one additional correction element with at least one third optically functional interface which has at least in sections a cylinder lens geometry or a cylinder lens-like geometry so that the at least one third optically functional interface has a direction which lies in a surface and along which at least in sections a curvature of the surface is essentially constant.

22. The imaging system as claimed in claim 21, wherein a direction of essentially constant curvature of the at least one third optically functional interface is aligned at an angle of roughly 45° to a direction of essentially constant curvature of at least the at least one first and the at least one second optically functional interfaces.

23. The imaging system as claimed in claim 21, wherein the at least one correction element has two third optically functional interfaces opposite one another, with a direction of essentially constant curvature being aligned essentially perpendicular to one another and at an angle of roughly 45° to the directions of essentially constant curvature of at least the at least one first and the at least one second optically functional interfaces.

24. The imaging system as claimed in claim 21, wherein the at least one third optically functional interface is concave.

25. The imaging system as claimed in claim 21, wherein the at least one third optically functional interface has a spherical or aspherical cylinder lens geometry or cylinder lens-like geometry.

26. The imaging system as claimed in claim 25, wherein the aspherical cylinder lens geometry or the cylinder lens-like geometry of the at least one third optically functional interface is formed by an elliptical, hyperbolic or parabolic cylinder section.

27. The imaging system as claimed in claim 21, wherein the are at least one lens element and the at least one correction element are on a common carrier.

28. The imaging system as claimed in claim 17, wherein the at least one lens elements are arrays or linear lines of identical lens elements.

29. The imaging system as claimed in claim 21, wherein the at least one correction elements are arrays or linear lines of identical correction elements.

30. An objective lens comprising an imaging system as claimed in claim 17.

31. A sensor comprising an imaging system as claimed in claim 17.

32. A camera comprising an imaging system as claimed in claim 17.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Alexei MIKHAILOV and
Dirk HAUSCHILD

Serial No.: **10/030,085**

Group Art Unit:

Examiner:

Filed : **January 11, 2002**

For : **IMAGING SYSTEM**

PRELIMINARY AMENDMENT B

Commissioner of Patents and Trademarks
Washington, D.C. 20231

ATTN: PCT BRANCH

Sir:

Please amend the above-identified application as follows:

In the Specification:

Please replace paragraphs 1-27, with the amended paragraphs provided.

Remarks

Applicants have amended the English translation of the application to conform with U.S. application practice. No new matter has been added, nor have any changes been made to overcome or address prior art. A marked-up copy and clean copy of the changes have been provided.

A signed Declaration/Power of Attorney is also enclosed.

Respectfully submitted,

Stewart L. Gitler
Reg. 31,256

March 5, 2002

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Attorney Docket: A-7752.PAMB/cat

IMAGING SYSTEM

Background of the Invention

[0001] This invention relates to an imaging system, especially an imaging system for imaging electromagnetic radiation in the optical spectral range, including at least one lens element and at least one first and one second optically functional boundary surface through which the electromagnetic radiation can pass, and at least the first and at least the second optically functional interface can be located either on one or on two or more lens elements, at least the first and at least the second optically functional interface having at least in sections a cylinder lens geometry or a cylinder lens-like geometry so that these optically functional interfaces each have a direction which lies in the interfaces and along which at least in sections the curvature of the surface is essentially constant, the direction of essentially constant curvature of at least the first optically functional interface to the direction of essentially constant curvature of at least the second optically functional interface being aligned roughly perpendicular to one another.

[0002] An imaging system of the aforementioned type is known from US patent US 5,844,723. The imaging system described therein is used for focusing the light emerging from the laser diode onto the entry surface of the optical fiber. To do this two cylinder lenses are used with cylinder axes which are perpendicular to one another. The disadvantage in this system is that the imaging errors which occur due to the two cylinder lenses which are crossed to one another cannot be compensated.

[0003] The object of this invention is to devise an imaging system of the initially mentioned type in which imaging errors can be largely avoided.

[0004] This object is achieved by the features of the invention. It is provided that at least the first and/or at least the second optically functional interface have an aspherical cylinder lens geometry or an aspherical cylinder lens-like geometry. The aspherical cylinder lens geometry can be formed, for example, by an elliptical or hyperbolic or parabolic cylinder section. By choosing the aspherical cylinder lens geometries for the optically functional interfaces of the lens elements, the difference of optical path lengths of the electromagnetic radiation passing through the imaging system is minimized so that planar wave fronts are present after passing through the imaging system.

Summary of the Invention

[0005] Imaging systems as depicted in the invention can be used for the entire optical spectral range from the vacuum-UV range into the far infrared range. It is also conceivable in the invention to use imaging systems in the x-ray range as long as the imaging takes place by refractive optically active interfaces.

[0006] It is possible in the invention for there to be at least two lens elements, on one of the lens elements there being the first optically functional interface and on the other of the lens elements the second optically functional interface. It is

also possible to provide each of the lens elements with two optically functional interfaces, then for example for each of the lens elements the optically functional interfaces opposite one another having cylinder lens geometries with directions of essentially constant curvature, i.e. with cylinder axes which are perpendicular. Alternatively, it is also possible to make each of the lens elements such that there are one first or second optically functional interface and one planar inlet and outlet surface opposite it at a time.

[0007] In addition or alternatively to the embodiment of the cylinder lens geometries of the first and the second optically active interface as aspherical cylinder geometries, there is the possibility of providing an additional correction element with at least a third optically functional interface which likewise has at least in sections a cylinder lens geometry or cylinder lens-like geometry so that this interface has a direction which lies in the surface along which at least in sections the curvature of the surface is essentially constant. By means of this additional correction element likewise imaging errors can be eliminated so that the corresponding wave fronts of the electromagnetic radiation passing through the imaging system are corrected or converted into planar wave fronts.

[0008] According to one preferred embodiment of this invention, the direction of essentially constant curvature of at least the third optically functional interface is aligned at an angle of roughly 45° to the directions of essentially constant

curvature of at least the first and at least the second optically functional interfaces. In this alignment of at least the third optically functional interface of the correction element, the imaging errors which are produced by the first and second optically functional interfaces, which are for example perpendicular to one another and which are provided with a spherical cylinder geometry, can be for the most part corrected. Advantageously it can be provided that the correction element has two third optically functional interfaces opposite one another with directions of essentially constant curvature perpendicular to one another and are aligned preferably at an angle of roughly 45° to the direction of essentially constant curvature of the first and the second optically functional interfaces. Here the third optically functional interfaces can be made concave.

[0009] As depicted in the invention it is possible to provide at least the third optically functional interface with a spherical or an aspherical cylinder lens geometry. Especially for an aspherical cylinder lens geometry of at least the third optically functional interface of the correction element can the imaging errors caused by the two lens elements be optimally corrected. The aspherical cylinder lens geometry can in turn be formed for example by an elliptical, hyperbolic or parabolic cylinder lens section.

[0010] It is possible to arrange the two lens elements and especially in addition the correction element on a common carrier. One such compact embodiment of the imaging system as

claimed in the invention can be used for example to focus the light emerging from a laser diode onto the entry surface of an optical fiber.

[0011] It is also possible to use the imaging system as claimed in the invention, for example in the form of an imaging system housed on a common carrier as a microobjective lens which can be designed in the invention to have a very wide angle.

[0012] In objective lenses with a very wide angle under certain circumstances, as a result of the correction of imaging errors which is very effective as in the invention, angles of more than 90° can be achieved with relatively good quality.

[0013] Here, under certain circumstances it can be especially advantageous, instead of lens elements, to use arrays or linear lines of especially identical lens elements. In addition, instead of correction elements, arrays or linear lines of especially identical correction elements can be used. Here it is especially advantageous that by using cylinder lenses or cylinder lens-like geometries rectangular or square lens elements and correction elements can be used so that arrays or linear lines of lens elements or correction elements with much better space utilization or with maximum attainable packing density can be prepared. These linear lines or two-dimensional arrays of lens elements and optically correction elements can be used for CCD cameras or CMOS cameras. It is also especially possible to use these imaging systems for process observation, for example for observation of welding processes.

Brief Description of the Figures

[0014] Other advantages and features of this invention become apparent from the following description of preferred embodiments with reference to the attached figures:

[0015] Figure 1a shows a side view of one embodiment of a imaging system as claimed in the invention;

[0016] Figure 1b shows a plan view of the imaging system as shown in Figure 1a;

[0017] Figure 1c shows a view along arrow Ic in Figure 1a;

[0018] Figure 2 shows perspective view of a correction element of the imaging system as shown in Figure 1;

[0019] Figure 3a shows a schematic of another embodiment of the imaging system as claimed in the invention; and

[0020] Figure 3b shows a plan view of the imaging system as shown in Figure 3a.

Detailed Description of the Invention

[0021] First, reference is made to Figure 1. The embodiment of the imaging system as shown therein includes two lens elements 1, 2 which are mounted on a carrier 3 essentially parallel to one another and spaced apart from one another. Between the two lens elements in the embodiment shown there is a correction element 4 which is likewise aligned essentially parallel to the two lens elements 1, 2 and is likewise mounted on the carrier 3. With the imaging system given by the two lens elements 1, 2 and the correction element 4, for example the light emerging from the laser diode 5 which is shown in Figure 1 can be focused on a

small space sector which is located in Figure 1a and Figure 1b in the right-hand part and which corresponds for example to the entry surface of an optical fiber.

[0022] The lens element 1 on its side which is the left side in Figure 1a and 1b has a planar entry surface 6 and on its right side an optically functional interface 7. Accordingly, the second lens element 2 on its left side has a planar entry surface 8 and on its right side an optically functional interface 9. In the embodiment shown, the first and the second optically functional interface 7, 9 in sections have a cylinder lens geometry, in the embodiment shown the cylinder lens geometry being formed by a cylinder section with a cross section with the shape of a sector. The two cylinder axes of these cylinder sections of the first and second optically functional interfaces 7, 9 are perpendicular to one another in the embodiment shown.

[0023] It is possible, instead of the spherical cylinder geometries, to use aspherical cylinder geometries for the first and the second optically functional interface 7, 9. In this way imaging errors which form in imaging with cylinder lenses crossed to one another are effectively compensated. In the embodiment shown, this compensation is furthermore undertaken by the additionally inserted correction element 4 which has the third optically functional interfaces 10, 11 which include one cylinder section 12, 13 at a time, as is apparent from Figure 2. These cylinder sections 12, 13 of the optically functional interfaces 10, 11 of the correction element 4 are perpendicular to one

another in the embodiment shown and at an angle of 45° to the cylinder axes of the optically functional interfaces 7, 9. It is possible to provide the optically functional interfaces 10, 11 of the correction element 4 with a spherical or aspherical cylinder lens geometry. For example elliptical, hyperbolic or parabolic cylinder geometries can be used as aspherical geometries.

[0024] Figure 3 shows one embodiment of the imaging system as in the invention which can be used as the objective lens. Here the light 15 emerging from the object 14 after passing through an aperture diaphragm 16 is imaged by two lens elements 17, 18 followed by one correction element 19 in the imaged embodiment. The light emerging from the correction element 19 in Figure 3 on the right side can for example strike a CCD sensor element or CMOS sensor element.

[0025] In the embodiment shown in Figure 3, each of the lens elements 17, 18 both on its entry and also its exit side has an optically functional interface with a cylinder lens geometry or cylinder lens-like geometry. As in the embodiment shown in Figure 1 and Figure 2 this cylinder lens geometry or cylinder lens-like geometry can be chosen as a spherical or aspherical cylinder lens geometry. In the embodiment shown the two optically functional interfaces of each of the lens elements 17, 18 are each provided with cylinder lens geometries which are perpendicular to one another. Furthermore, in the embodiment shown the correction element 19 is provided with an optically

functional interface with a cylinder lens geometry only on its entry surface. On its exit surface the correction element 19 is planar in the embodiment shown.

[0026] As shown in the invention it is possible to combine the imaging systems shown in Figure 3 for example which consist of two lens elements 17, 18 and optionally a correction element 19 and optionally an aperture diaphragm 16 into lines or arrays so that they can be assigned to linear lines of camera sensors or two-dimensional fields of camera sensors.

ABSTRACT OF THE DISCLOSURE

[0027] This invention relates to an imaging system, especially an imaging system for imaging electromagnetic radiation in the optical spectral range, including at least one lens element and at least one first and one second optically functional boundary surface through which the electromagnetic radiation can pass, and at least the first and at least the second optically functional interface can be located either on one or on two or more lens elements, at least the first and at least the second optically functional interface having at least in sections a cylinder lens geometry or a cylinder lens-like geometry so that these optically functional interfaces each have a direction which lies in the interfaces and along which at least in sections the curvature of the surface is essentially constant, the direction of essentially constant curvature of at least the first optically functional interface to the direction of essentially constant curvature of at least the second optically functional interface being aligned roughly perpendicular to one another.

"Marked-Up Specification"

IMAGING SYSTEM

Background of the Invention

[0001] This invention relates to an imaging system, especially an imaging system for imaging electromagnetic radiation in the optical spectral range, [comprising] including at least one lens element and at least one first and one second optically functional boundary surface through which the electromagnetic radiation can pass, and at least the first and at least the second optically functional interface can be located either on one or on two or more lens elements, at least the first and at least the second optically functional interface having at least in sections a cylinder lens geometry or a cylinder lens-like geometry so that these optically functional interfaces each have a direction which lies in the interfaces and along which at least in sections the curvature of the surface is essentially constant, the direction of essentially constant curvature of at least the first optically functional interface to the direction of essentially constant curvature of at least the second optically functional interface being aligned roughly perpendicular to one another.

[0002] An imaging system of the aforementioned type is known from US patent US 5,844,723. The imaging system described therein is used for [focussing] focusing the light emerging from the laser diode onto the entry surface of the optical fiber. To do this two cylinder lenses are used with cylinder axes which are

perpendicular to one another. The disadvantage in this system is that the imaging errors which occur due to the two cylinder lenses which are crossed to one another cannot be compensated.

[0003] The object of this invention is to devise an imaging system of the initially mentioned type in which imaging errors can be largely avoided.

[0004] This object is achieved by the features of [claims 1 and 5] of the invention. [As claimed in claim 1 it] It is provided that at least the first and/or at least the second optically functional interface have an aspherical cylinder lens geometry or an aspherical cylinder lens-like geometry. The aspherical cylinder lens geometry can be formed, for example, by an elliptical or hyperbolic or parabolic cylinder section. By choosing the aspherical cylinder lens geometries for the optically functional interfaces of the lens elements, the difference of optical path lengths of the electromagnetic radiation passing through the imaging system is minimized so that planar wave fronts are present after passing through the imaging system.

Summary of the Invention

[0005] Imaging systems as [claimed] depicted in the invention can be used for the entire optical spectral range from the vacuum-UV range into the far infrared range. It is also conceivable [as claimed] in the invention to use imaging systems [as claimed in the invention] in the x-ray range as long as the imaging takes place by refractive optically active interfaces.

[0006] It is possible [as claimed] in the invention for there to be at least two lens elements, on one of the lens elements there being the first optically functional interface and on the other of the lens elements the second optically functional interface. It is also possible to provide each of the lens elements with two optically functional interfaces, then for example for each of the lens elements the optically functional interfaces opposite one another having cylinder lens geometries with directions of essentially constant curvature, i.e. with cylinder axes which are perpendicular. Alternatively, it is also possible to make each of the lens elements such that there are one first or second optically functional interface and one planar inlet and outlet surface opposite it at a time.

[0007] In addition or alternatively to the embodiment of the cylinder lens geometries of the first and the second optically active interface as aspherical cylinder geometries,[as claimed in claim 5] there is the possibility of providing an additional correction element with at least a third optically functional interface which likewise has at least in sections a cylinder lens geometry or cylinder lens-like geometry so that this interface has a direction which lies in the surface along which at least in sections the curvature of the surface is essentially constant. By means of this additional correction element likewise imaging errors can be eliminated so that the corresponding wave fronts of the electromagnetic radiation passing through the imaging system are corrected or converted into planar wave fronts.

[0008] According to one preferred embodiment of this invention, the direction of essentially constant curvature of at least the third optically functional interface is aligned at an angle of roughly 45° to the directions of essentially constant curvature of at least the first and at least the second optically functional interfaces. In this alignment of at least the third optically functional interface of the correction element, the imaging errors which are produced by the first and second optically functional interfaces, which are for example perpendicular to one another and which are provided with a spherical cylinder geometry, can be for the most part corrected. Advantageously it can be provided that the correction element has two third optically functional interfaces opposite one another with directions of essentially constant curvature perpendicular to one another and are aligned preferably at an angle of roughly 45° to the direction of essentially constant curvature of the first and the second optically functional interfaces. Here the third optically functional interfaces can be made concave.

[0009] As [claimed] depicted in the invention it is possible to provide at least the third optically functional interface with a spherical or an aspherical cylinder lens geometry. Especially for an aspherical cylinder lens geometry of at least the third optically functional interface of the correction element can the imaging errors caused by the two lens elements be optimally corrected. The aspherical cylinder lens geometry can in turn be

formed for example by an elliptical, hyperbolic or parabolic cylinder lens section.

[0010] It is possible to arrange the two lens elements and especially in addition the correction element on a common carrier. One such compact embodiment of the imaging system as claimed in the invention can be used for example to focus the light emerging from a laser diode onto the entry surface of an optical fiber.

[0011] It is also possible to use the imaging system as claimed in the invention, for example in the form of an imaging system housed on a common carrier as a microobjective lens which can be designed [as claimed] in the invention to have a very wide angle.

[0012] In objective lenses with a very wide angle under certain circumstances, as a result of the correction of imaging errors which is very effective as [claimed] in the invention, angles of more than 90° can be achieved with relatively good quality.

[0013] Here, under certain circumstances it can be especially advantageous, instead of lens elements, to use arrays or linear lines of especially identical lens elements. In addition, instead of correction elements, arrays or linear lines of especially identical correction elements can be used. Here it is especially advantageous that by using cylinder lenses or cylinder lens-like geometries rectangular or square lens elements and correction elements can be used so that arrays or linear

lines of lens elements or correction elements with much better space utilization or with maximum attainable packing density can be prepared. These linear lines or two-dimensional arrays of lens elements and optically correction elements can be used for CCD cameras or CMOS cameras. It is also especially possible to use these imaging systems for process observation, for example for observation of welding processes.

Brief Description of the Figures

[0014] Other advantages and features of this invention become apparent from the following description of preferred embodiments with reference to the attached figures[.]:

[0015] Figure 1a shows a side view of one embodiment of a imaging system as claimed in the invention;

[0016] Figure 1b shows a plan view of the imaging system as shown in Figure 1a;

[0017] Figure 1c shows a view along arrow Ic in Figure 1a;

[0018] Figure 2 shows perspective view of a correction element of the imaging system as shown in Figure 1;

[0019] Figure 3a shows a schematic of another embodiment of the imaging system as claimed in the invention; and

[0020] Figure 3b shows a plan view of the imaging system as shown in Figure 3a.

Detailed Description of the Invention

[0021] First, reference is made to Figure 1. The embodiment of the imaging system as [claimed in the invention] shown therein [comprises] includes two lens elements 1, 2 which are mounted on

a carrier 3 essentially parallel to one another and spaced apart from one another. Between the two lens elements in the embodiment shown there is a correction element 4 which is likewise aligned essentially parallel to the two lens elements 1, 2 and is likewise mounted on the carrier 3. With the imaging system given by the two lens elements 1, 2 and the correction element 4, for example the light emerging from the laser diode 5 which is shown in Figure 1 can be [focussed] focused on a small space sector which is located in Figure 1a and Figure 1b in the right-hand part and which corresponds for example to the entry surface of an optical fiber.

[0022] The lens element 1 on its side which is the left side in Figure 1a and 1b has a planar entry surface 6 and on its right side an optically functional interface 7. Accordingly, the second lens element 2 on its left side has a planar entry surface 8 and on its right side an optically functional interface 9. In the embodiment shown, the first and the second optically functional interface 7, 9 in sections have a cylinder lens geometry, in the embodiment shown the cylinder lens geometry being formed by a cylinder section with a cross section with the shape of a sector. The two cylinder axes of these cylinder sections of the first and second optically functional interfaces 7, 9 are perpendicular to one another in the embodiment shown.

[0023] It is possible, instead of the spherical cylinder geometries, to use aspherical cylinder geometries for the first and the second optically functional interface 7, 9. In this way

imaging errors which form in imaging with cylinder lenses crossed to one another are effectively compensated. In the embodiment shown, this compensation is furthermore undertaken by the additionally inserted correction element 4 which has the third optically functional interfaces 10, 11 which [comprise] include one cylinder section 12, 13 at a time, as is apparent from Figure 2. These cylinder sections 12, 13 of the optically functional interfaces 10, 11 of the correction element 4 are perpendicular to one another in the embodiment shown and at an angle of 45° to the cylinder axes of the optically functional interfaces 7, 9. It is possible to provide the optically functional interfaces 10, 11 of the correction element 4 with a spherical or aspherical cylinder lens geometry. For example elliptical, hyperbolic or parabolic cylinder geometries can be used as aspherical geometries.

[0024] Figure 3 shows one embodiment of the imaging system as [claimed] in the invention which can be used as the objective lens. Here the light 15 emerging from the object 14 after passing through an aperture diaphragm 16 is imaged by two lens elements 17, 18 followed by one correction element 19 in the imaged embodiment. The light emerging from the correction element 19 in Figure 3 on the right side can for example strike a CCD sensor element or CMOS sensor element.

[0025] In the embodiment shown in Figure 3, each of the lens elements 17, 18 both on its entry and also its exit side has an optically functional interface with a cylinder lens geometry or

cylinder lens-like geometry. As in the embodiment shown in Figure 1 and Figure 2 this cylinder lens geometry or cylinder lens-like geometry can be chosen as a spherical or aspherical cylinder lens geometry. In the embodiment shown the two optically functional interfaces of each of the lens elements 17, 18 are each provided with cylinder lens geometries which are perpendicular to one another. Furthermore, in the embodiment shown the correction element 19 is provided with an optically functional interface with a cylinder lens geometry only on its entry surface. On its exit surface the correction element 19 is planar in the embodiment shown.

[0026] As [claimed] shown in the invention it is possible to combine the imaging systems shown in Figure 3 for example which consist of two lens elements 17, 18 and optionally a correction element 19 and optionally an aperture diaphragm 16 into lines or arrays so that they can be assigned to linear lines of camera sensors or two-dimensional fields of camera sensors.

ABSTRACT OF THE DISCLOSURE

[0027] This invention relates to an imaging system, especially an imaging system for imaging electromagnetic radiation in the optical spectral range, including at least one lens element and at least one first and one second optically functional boundary surface through which the electromagnetic radiation can pass, and at least the first and at least the second optically functional interface can be located either on one or on two or more lens elements, at least the first and at least the second optically functional interface having at least in sections a cylinder lens geometry or a cylinder lens-like geometry so that these optically functional interfaces each have a direction which lies in the interfaces and along which at least in sections the curvature of the surface is essentially constant, the direction of essentially constant curvature of at least the first optically functional interface to the direction of essentially constant curvature of at least the second optically functional interface being aligned roughly perpendicular to one another.

Translation

Imaging System

This invention relates to an imaging system, especially an imaging system for imaging electromagnetic radiation in the optical spectral range, comprising at least one lens element and at least one first and one second optically functional boundary surface through which the electromagnetic radiation can pass, and at least the first and at least the second optically functional interface can be located either on one or on two or more lens elements, at least the first and at least the second optically functional interface having at least in sections a cylinder lens geometry or a cylinder lens-like geometry so that these optically functional interfaces each have a direction which lies in the interfaces and along which at least in sections the curvature of the surface is essentially constant, the direction of essentially constant curvature of at least the first optically functional interface to the direction of essentially constant curvature of at least the second optically functional interface being aligned roughly perpendicular to one another.

An imaging system of the aforementioned type is known from US patent US 5,844,723. The imaging system described therein is used for focussing the light emerging from the laser diode onto the entry surface of the optical fiber. To do this two cylinder lenses are used with cylinder axes which are perpendicular to one another. The disadvantage in this system is that the imaging

errors which occur due to the two cylinder lenses which are crossed to one another cannot be compensated.

The object of this invention is to devise an imaging system of the initially mentioned type in which imaging errors can be largely avoided.

This object is achieved by the features of claims 1 and 5. As claimed in claim 1 it is provided that at least the first and/or at least the second optically functional interface have an aspherical cylinder lens geometry or an aspherical cylinder lens-like geometry. The aspherical cylinder lens geometry can be formed for example by an elliptical or hyperbolic or parabolic cylinder section. By choosing the aspherical cylinder lens geometries for the optically functional interfaces of the lens elements the difference of optical path lengths of the electromagnetic radiation passing through the imaging system is minimized so that planar wave fronts are present after passing through the imaging system.

Imaging systems as claimed in the invention can be used for the entire optical spectral range from the vacuum-UV range into the far infrared range. It is also conceivable as claimed in the invention to use imaging systems as claimed in the invention in the x-ray range as long as the imaging takes place by refractive optically active interfaces.

It is possible as claimed in the invention for there to be at least two lens elements, on one of the lens elements there being the first optically functional interface and on the other of the lens elements the second optically functional interface.

It is also possible to provide each of the lens elements with two optically functional interfaces, then for example for each of the lens elements the optically functional interfaces opposite one another having cylinder lens geometries with directions of essentially constant curvature, i.e. with cylinder axes which are perpendicular. Alternatively it is also possible to make each of the lens elements such that there are one first or second optically functional interface and one planar inlet and outlet surface opposite it at a time.

In addition or alternatively to the embodiment of the cylinder lens geometries of the first and the second optically active interface as aspherical cylinder geometries, as claimed in claim 5 there is the possibility of providing an additional correction element with at least a third optically functional interface which likewise has at least in sections a cylinder lens geometry or cylinder lens-like geometry so that this interface has a direction which lies in the surface along which at least in sections the curvature of the surface is essentially constant. By means of this additional correction element likewise imaging errors can be eliminated so that the corresponding wave fronts of the electromagnetic radiation passing through the imaging system are corrected or converted into planar wave fronts.

According to one preferred embodiment of this invention the direction of essentially constant curvature of at least the third optically functional interface is aligned at an angle of roughly 45° to the directions of essentially constant curvature of at least the first and at least the second optically functional

interfaces. In this alignment of at least the third optically functional interface of the correction element the imaging errors which are produced by the first and second optically functional interfaces which are for example perpendicular to one another and which are provided with a spherical cylinder geometry can be for the most part corrected. Advantageously it can be provided that the correction element has two third optically functional interfaces opposite one another with directions of essentially constant curvature perpendicular to one another and are aligned preferably at an angle of roughly 45° to the direction of essentially constant curvature of the first and the second optically functional interfaces. Here the third optically functional interfaces can be made concave.

As claimed in the invention it is possible to provide at least the third optically functional interface with a spherical or an aspherical cylinder lens geometry. Especially for an aspherical cylinder lens geometry of at least the third optically functional interface of the correction element can the imaging errors caused by the two lens elements be optimally corrected. The aspherical cylinder lens geometry can in turn be formed for example by an elliptical, hyperbolic or parabolic cylinder lens section.

It is possible to arrange the two lens elements and especially in addition the correction element on a common carrier. One such compact embodiment of the imaging system as claimed in the invention can be used for example to focus the

light emerging from a laser diode onto the entry surface of an optical fiber.

It is also possible to use the imaging system as claimed in the invention, for example in the form of an imaging system housed on a common carrier as a microobjective lens which can be designed as claimed in the invention to have a very wide angle.

In objective lenses with a very wide angle under certain circumstances, as a result of the correction of imaging errors which is very effective as claimed in the invention, angles of more than 90° can be achieved with relatively good quality.

Here, under certain circumstances it can be especially advantageous, instead of lens elements, to use arrays or linear lines of especially identical lens elements. In addition, instead of correction elements, arrays or linear lines of especially identical correction elements can be used. Here it is especially advantageous that by using cylinder lenses or cylinder lens-like geometries rectangular or square lens elements and correction elements can be used so that arrays or linear lines of lens elements or correction elements with much better space utilization or with maximum attainable packing density can be prepared. These linear lines or two-dimensional arrays of lens elements and optically correction elements can be used for CCD cameras or CMOS cameras. It is also especially possible to use these imaging systems for process observation, for example for observation of welding processes.

Other advantages and features of this invention become apparent from the following description of preferred embodiments with reference to the attached figures.

Figure 1a shows a side view of one embodiment of a imaging system as claimed in the invention;

Figure 1b shows a plan view of the imaging system as shown in Figure 1a;

Figure 1c shows a view along arrow Ic in Figure 1a;

Figure 2 shows perspective view of a correction element of the imaging system as shown in Figure 1;

Figure 3a shows a schematic of another embodiment of the imaging system as claimed in the invention;

Figure 3b shows a plan view of the imaging system as shown in Figure 3a.

First, reference is made to Figure 1. The embodiment of the imaging system as claimed in the invention shown therein comprises two lens elements 1, 2 which are mounted on a carrier 3 essentially parallel to one another and spaced apart from one another. Between the two lens elements in the embodiment shown there is a correction element 4 which is likewise aligned essentially parallel to the two lens elements 1, 2 and is likewise mounted on the carrier 3. With the imaging system given by the two lens elements 1, 2 and the correction element 4, for example the light emerging from the laser diode 5 which is shown in Figure 1 can be focussed on a small space sector which is located in Figure 1a and Figure 1b in the right-hand part and

which corresponds for example to the entry surface of an optical fiber.

The lens element 1 on its side which is the left side in Figure 1a and 1b has a planar entry surface 6 and on its right side an optically functional interface 7. Accordingly the second lens element 2 on its left side has a planar entry surface 8 and on its right side an optically functional interface 9. In the embodiment shown, the first and the second optically functional interface 7, 9 in sections have a cylinder lens geometry, in the embodiment shown the cylinder lens geometry being formed by a cylinder section with a cross section with the shape of a sector. The two cylinder axes of these cylinder sections of the first and second optically functional interfaces 7, 9 are perpendicular to one another in the embodiment shown.

It is possible, instead of the spherical cylinder geometries, to use aspherical cylinder geometries for the first and the second optically functional interface 7, 9. In this way imaging errors which form in imaging with cylinder lenses crossed to one another are effectively compensated. In the embodiment shown, this compensation is furthermore undertaken by the additionally inserted correction element 4 which has the third optically functional interfaces 10, 11 which comprise one cylinder section 12, 13 at a time, as is apparent from Figure 2. These cylinder sections 12, 13 of the optically functional interfaces 10, 11 of the correction element 4 are perpendicular to one another in the embodiment shown and at an angle of 45° to the cylinder axes of the optically functional interfaces 7, 9.

It is possible to provide the optically functional interfaces 10, 11 of the correction element 4 with a spherical or aspherical cylinder lens geometry. For example elliptical, hyperbolic or parabolic cylinder geometries can be used as aspherical geometries.

Figure 3 shows one embodiment of the imaging system as claimed in the invention which can be used as the objective lens. Here the light 15 emerging from the object 14 after passing through an aperture diaphragm 16 is imaged by two lens elements 17, 18 followed by one correction element 19 in the imaged embodiment. The light emerging from the correction element 19 in Figure 3 on the right side can for example strike a CCD sensor element or CMOS sensor element.

In the embodiment shown in Figure 3, each of the lens elements 17, 18 both on its entry and also its exit side has an optically functional interface with a cylinder lens geometry or cylinder lens-like geometry. As in the embodiment shown in Figure 1 and Figure 2 this cylinder lens geometry or cylinder lens-like geometry can be chosen as a spherical or aspherical cylinder lens geometry. In the embodiment shown the two optically functional interfaces of each of the lens elements 17, 18 are each provided with cylinder lens geometries which are perpendicular to one another. Furthermore, in the embodiment shown the correction element 19 is provided with an optically functional interface with a cylinder lens geometry only on its entry surface. On its exit surface the correction element 19 is planar in the embodiment shown.

As claimed in the invention it is possible to combine the imaging systems shown in FIgure 3 for example which consist of two lens elements 17, 18 and optionally a correction element 19 and optionally an aperture diaphragm 16 into lines or arrays so that they can be assigned to linear lines of camera sensors or two-dimensional fields of camera sensors.

Fig. 1a

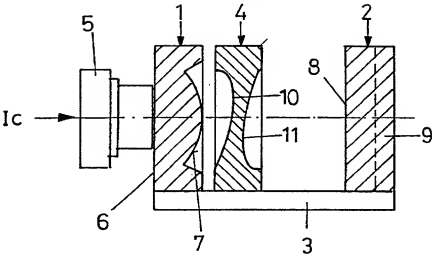
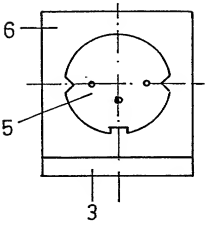


Fig. 1c



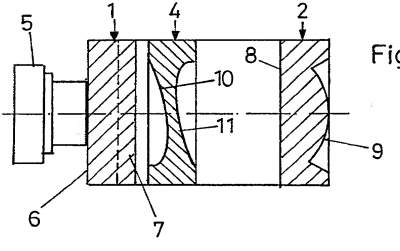


Fig. 1b

Fig. 2

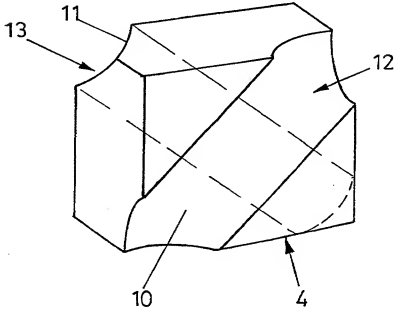


Fig. 3a

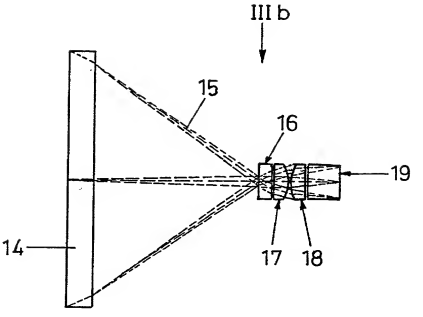
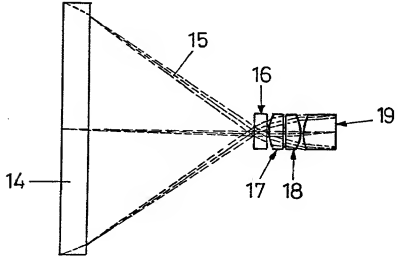


Fig. 3b



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Erklärung für Patentanmeldungen mit Vollmacht

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Abbildungssystem

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As a below named inventor, I hereby declare that:

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I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Imaging System

the specification of which is attached hereto unless the following box is checked:

☒ was filed on January 11, 2002 as United States Application Number or PCT International Application 10/030,085 and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

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Prior Foreign Applications (Frühere ausländische Anmeldungen)			Priority Not Claimed Priorität nicht beansprucht
199 32 592.8 (Number) (Nummer)	Germany (Country) (Land)	13/07/1999 (Day/Month/Year Filed) (Tag/Monat/Jahr der Anmeldung)	☐
PCT/EP00/05935 (Number) (Nummer)	PCT (Country) (Land)	27/06/2000 (Day/Month/Year Filed) (Tag/Monat/Jahr der Anmeldung)	☐

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(Application No.) (Aktenzeichen)	(Filing Date) (Anmeldetag)
(Application No.) (Aktenzeichen)	(Filing Date) (Anmeldetag)

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(Application No.) (Aktenzeichen)	(Filing Date) (Anmeldetag)	(Status) (patented, pending, abandoned) (Status) (patentiert, schwebend, aufgegeben)
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